



Dynamic Systems Analysis

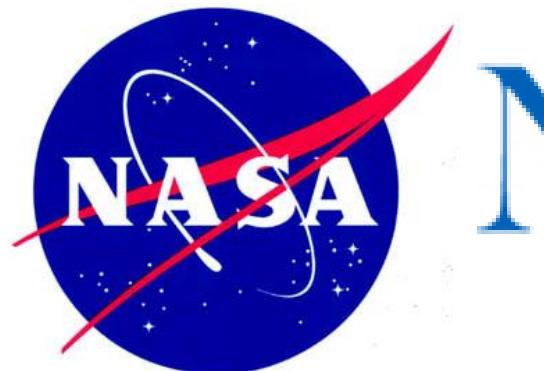
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*4th Propulsion Control and Diagnostics Workshop
Ohio Aerospace Institute (OAI)
Cleveland, OH
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Team Members

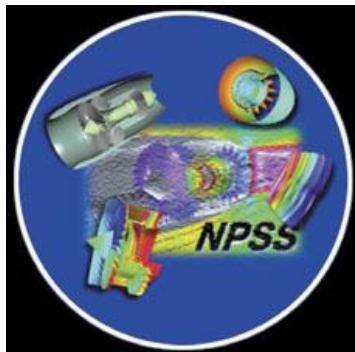
- Jonathan Seidel, NASA Glenn Research Center/RTM
- Jeffrey Chin, NASA Glenn Research Center/RTM
- Alicia Zinnecker, N&R Engineering
- Georgia Institute of Technology



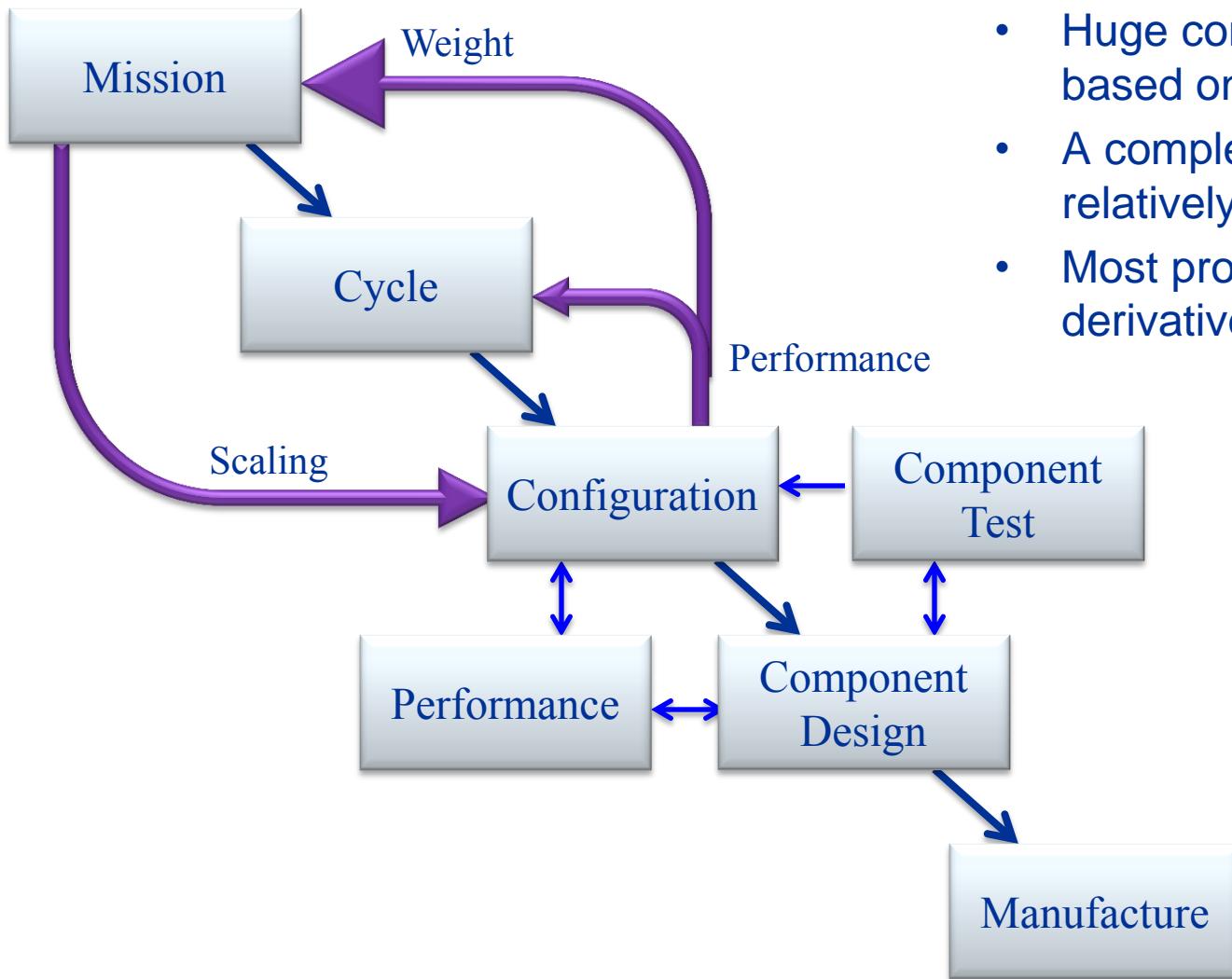


Outline

- Preliminary Engine Design
- Systems Analysis
- Tool for Turbine Engine Closed-loop Transient Analysis (TTECTrA)
- Dynamic Systems Analysis
- Conclusion



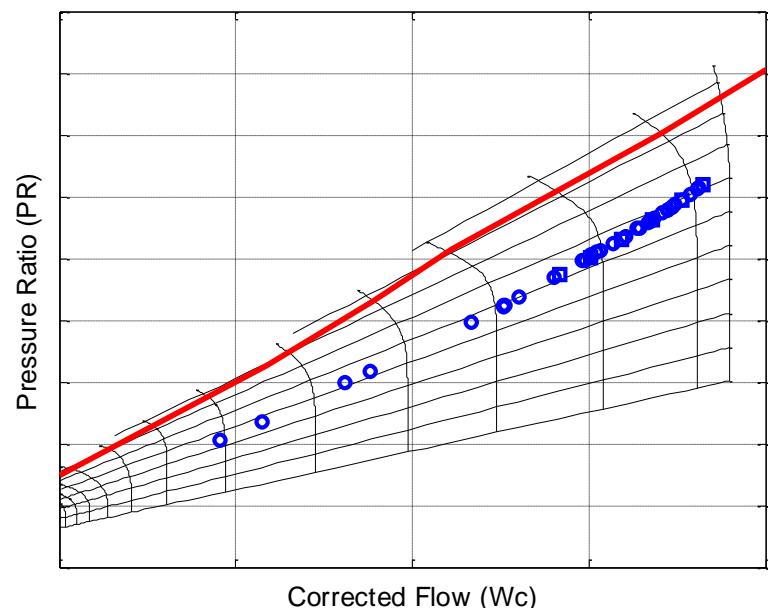
Preliminary Engine Design



- Huge commitments are made based on results
- A completely new engine is relatively rare
- Most programs focus on derivative engines

Systems Analysis

- Complex process that involves system-level simulations to evaluate system-level performance, weight, and cost (optimize system, compromise component)
- Focus on steady-state design cycle performance
- Dynamic considerations and issues are incorporated through the use of operating margins
 - Stall margin

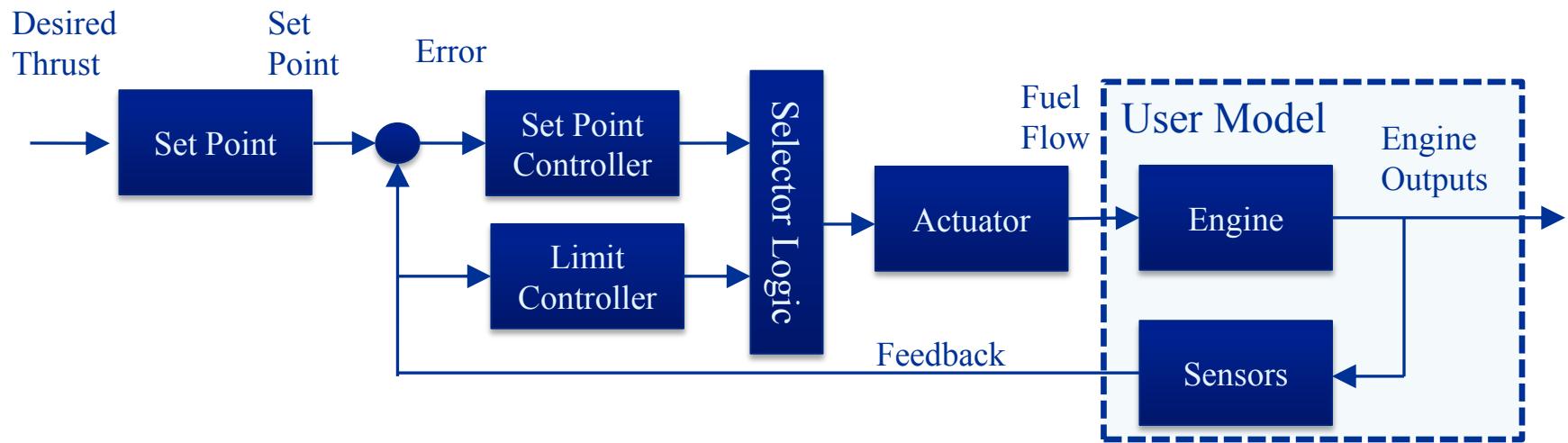




Tool for Turbine Engine Closed-loop Transient Analysis (TTECTrA)

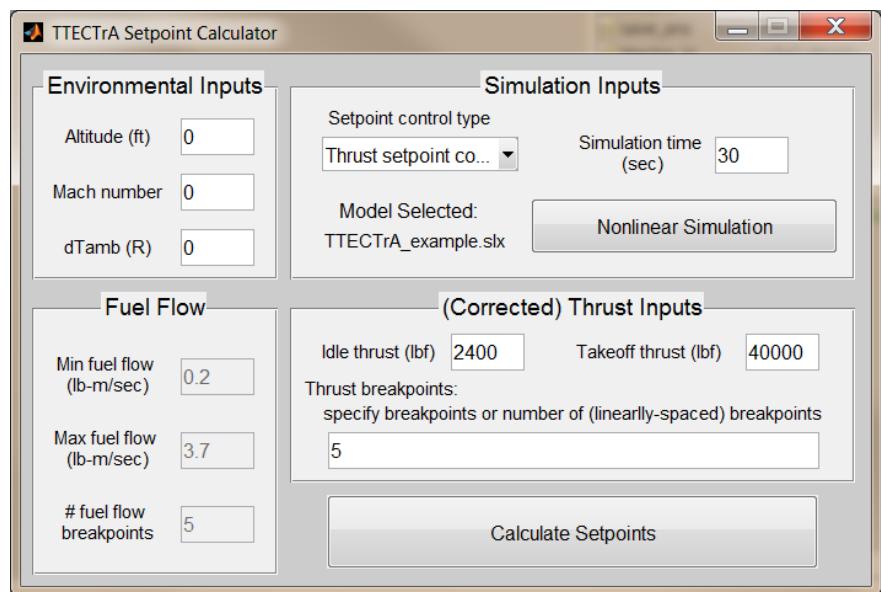
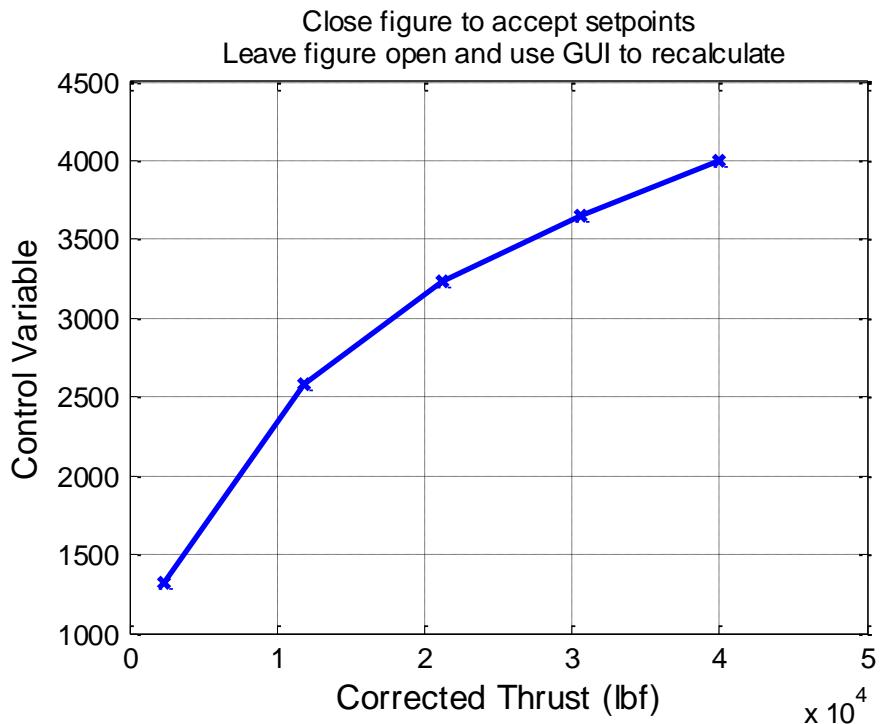
- Capable of automatically designing a controller
- Easily integrates with users engine model in MATLAB/Simulink environment
- Provide an estimate of the closed-loop transient performance/capability of a conceptual engine design
- Requirements:
 - MATLAB®/Simulink® (Release R2012b or later)
 - MATLAB® Version 8.0 (R2012b)
 - Simulink® Version 8.0 (R2012b)
 - Control Systems Toolbox® Version 9.4 (R2012b)
 - Engine Model compatible with Simulink
 - State space linear model in MATLAB

TTECTrA Architecture



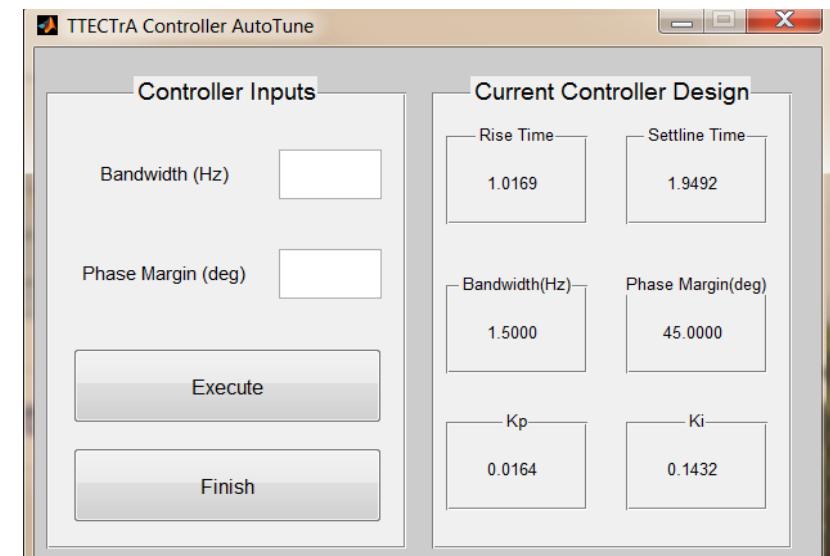
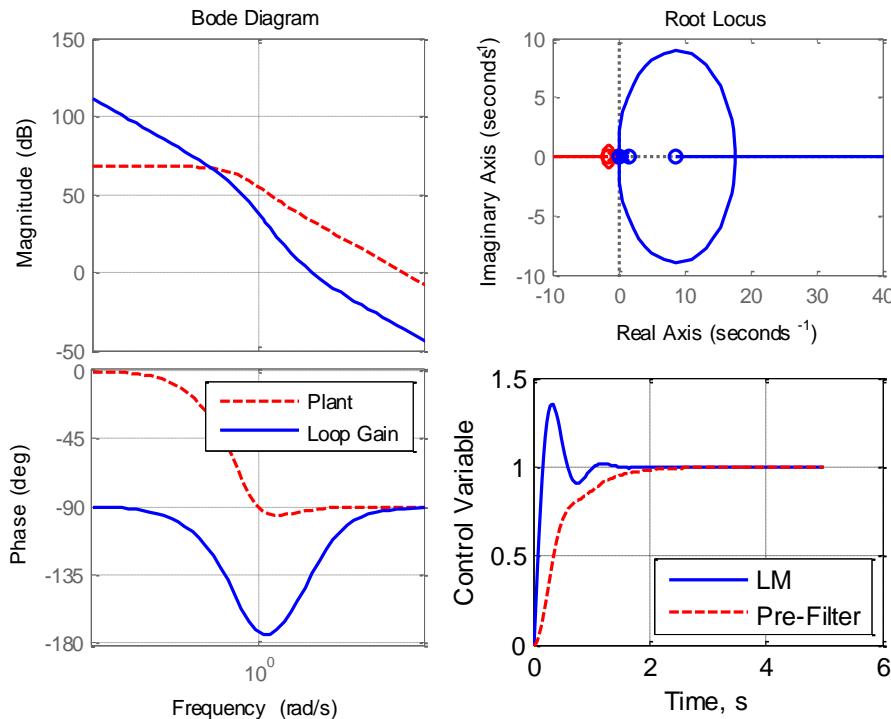
- TTECTrA software automatically designs:
 - Set Point
 - Set Point Controller
 - Limit Controller
- Simulates different thrust profiles

TTECTrA - Set Point Function



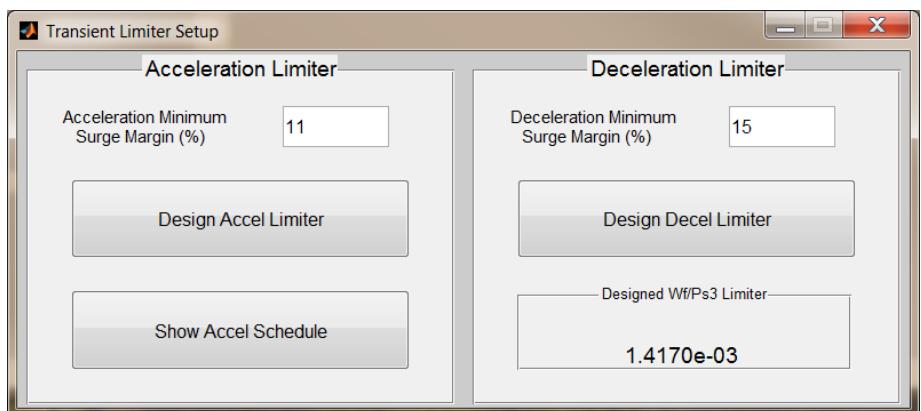
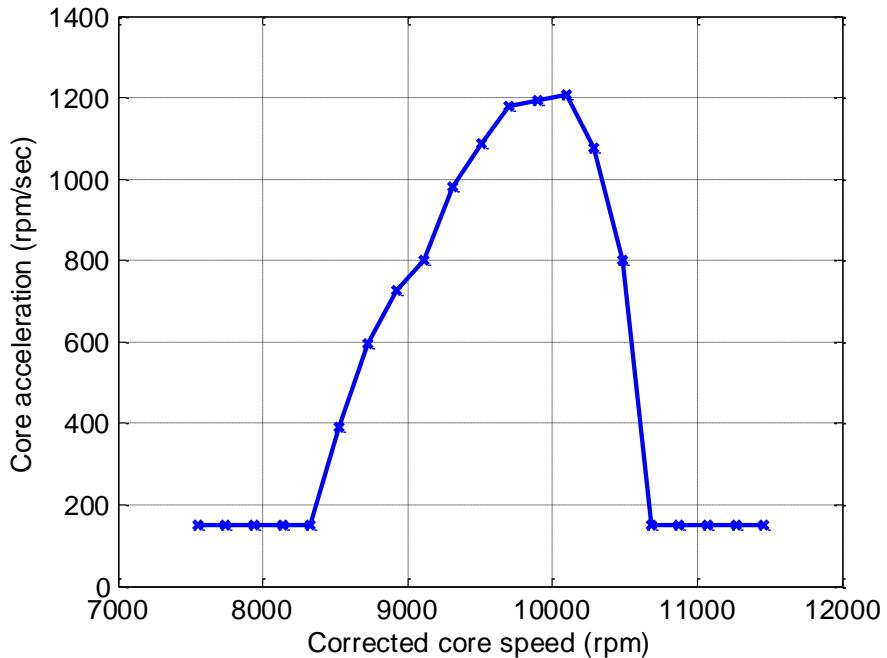
- Flight condition (altitude, Mach, temperature)
- Define set point bounds and number of breakpoints
 - Fuel flow
 - Thrust

TTECTrA – Set Point Controller



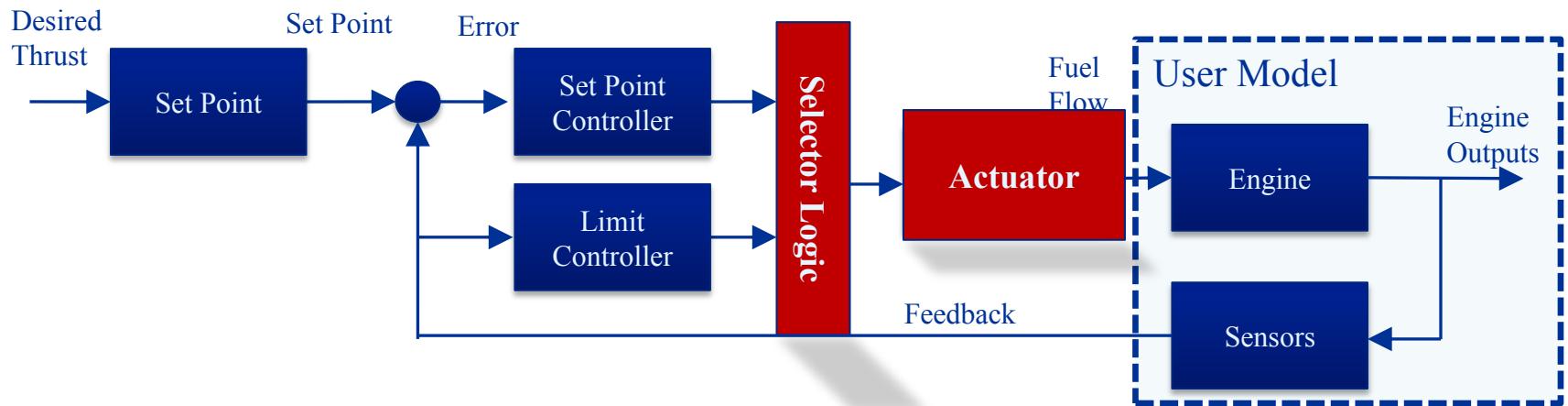
- Bandwidth (Hz)
- Phase Margin
- *Feedback filter (Hz)*
- *Throttle Filter (Hz)*

TTECTrA – Limit Controller



- Acceleration Minimum Surge Margin (HPC)
 - N_cdot vs N_cR25
- Deceleration Minimum Surge Margin (LPC)
 - W_f/P_{s3}

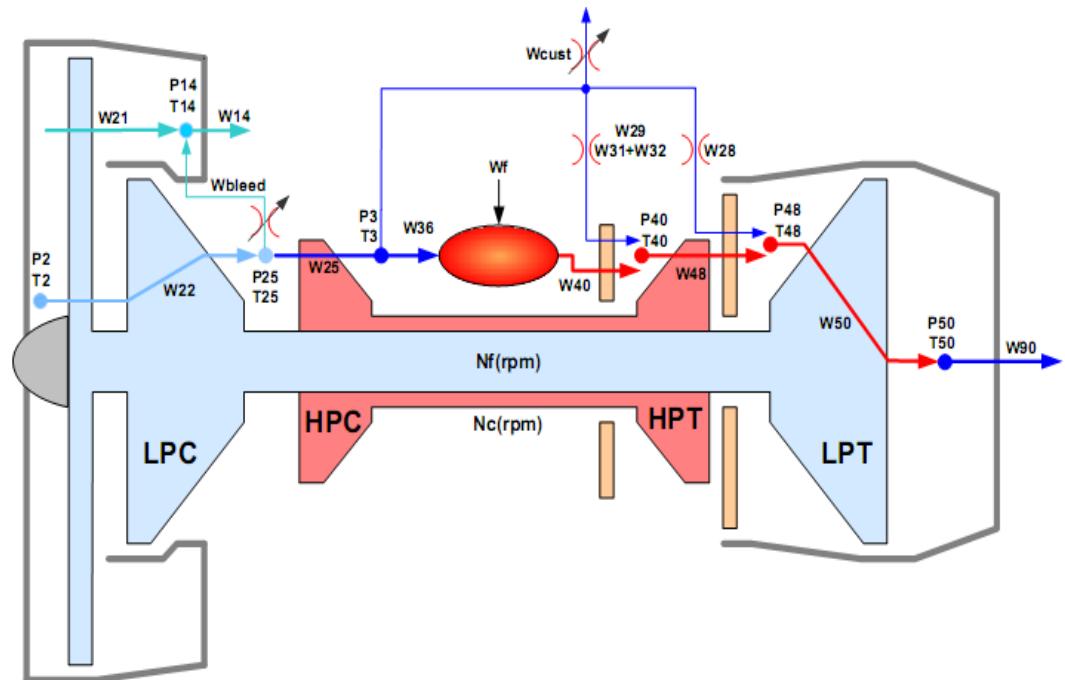
TTECTrA - Selector Logic / Actuator



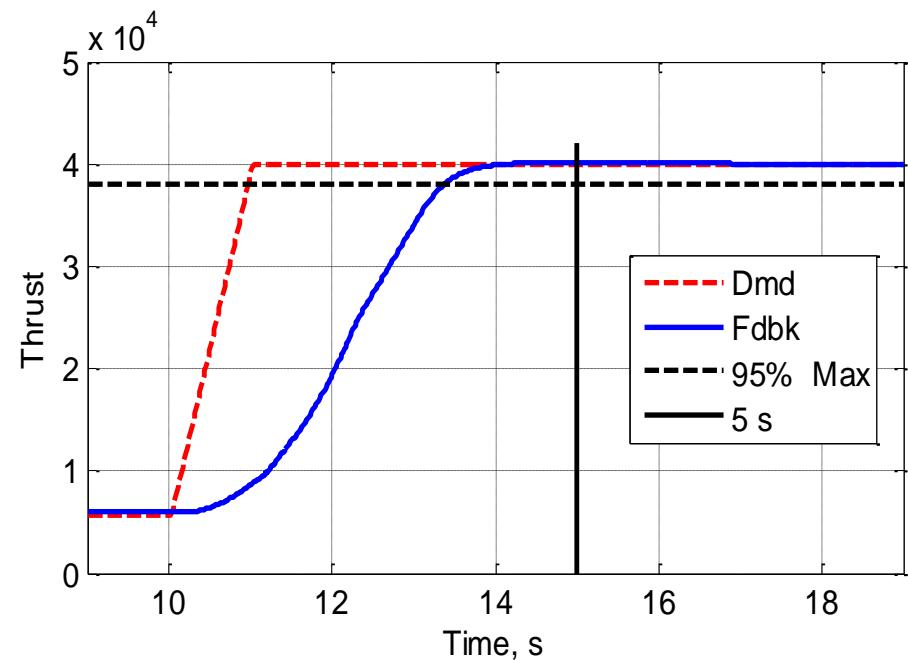
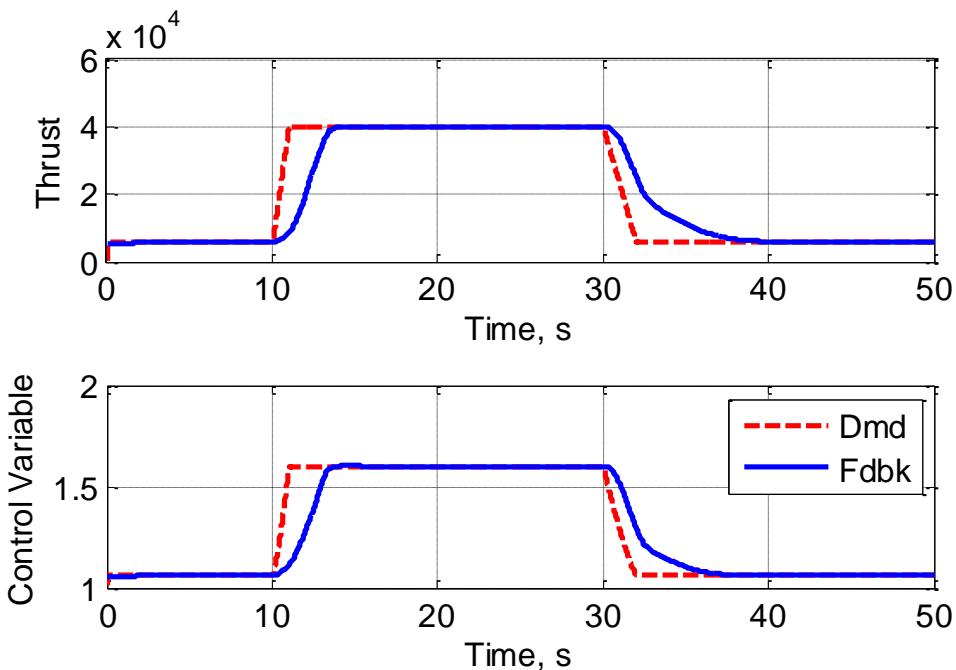
- Selector Logic (Min/Max scheme)
 - Min (Set Point, Acceleration)
 - Max (Min, Deceleration)
- Actuators
 - Currently only models fuel flow
 - First order filter

Commercial Modular Aero Propulsion System Simulator 40,000 (C-MAPSS40k)

- 40,000 Lb Thrust Class High Bypass Turbofan Engine Simulation
- Matlab/Simulink Environment
- Publically available
- Realistic controller
- Realistic surge margin calculations

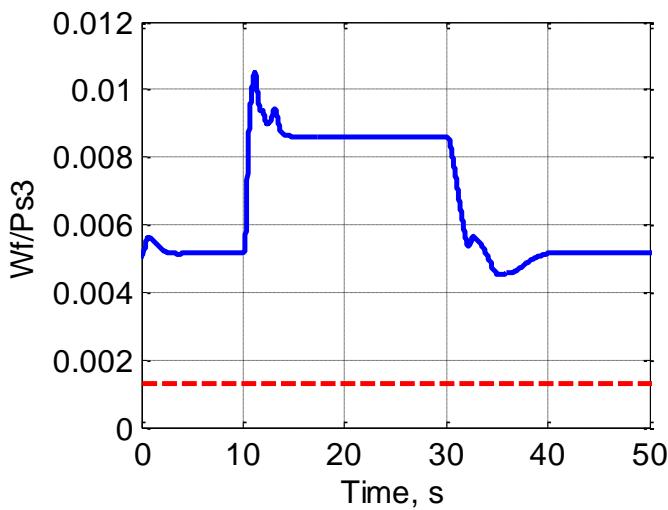
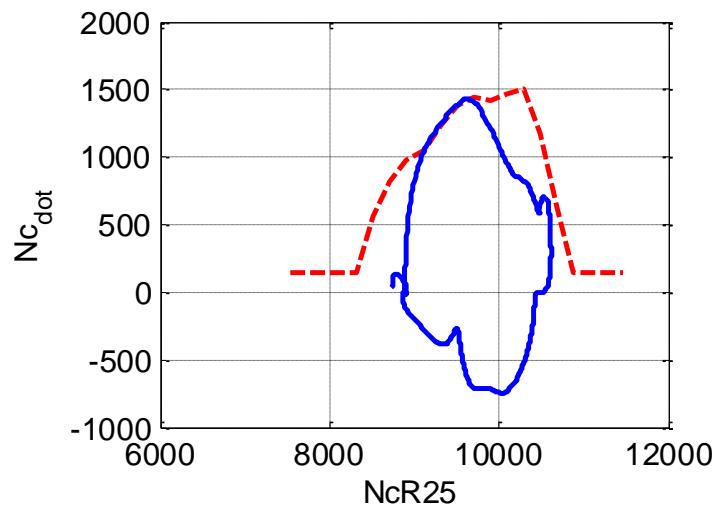
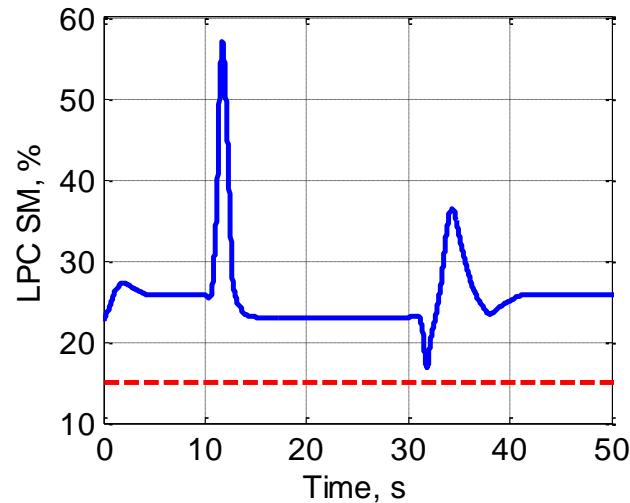
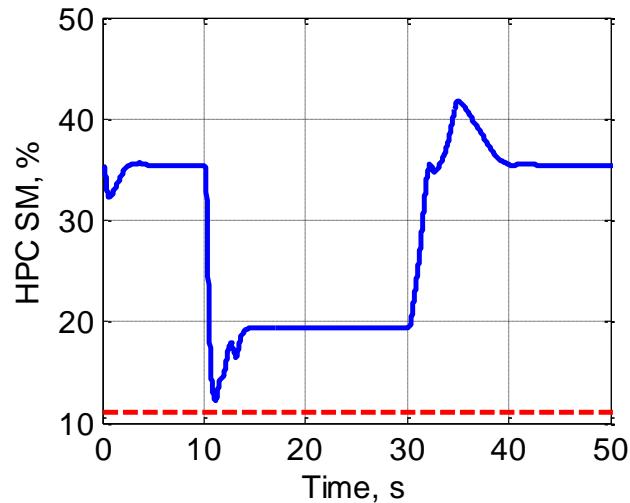


Burst and Chop Thrust Profile

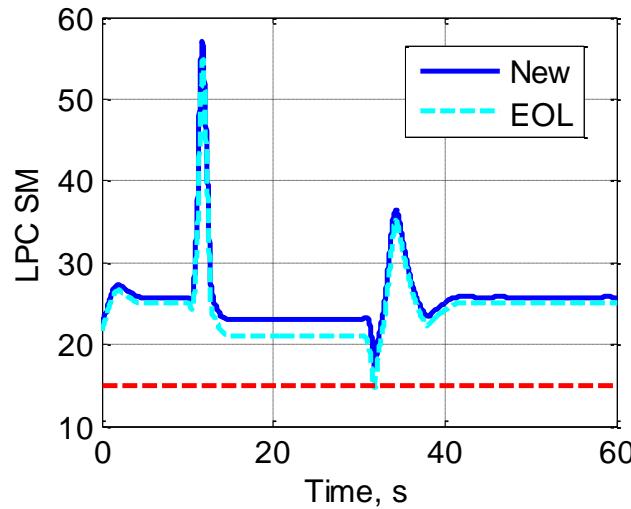
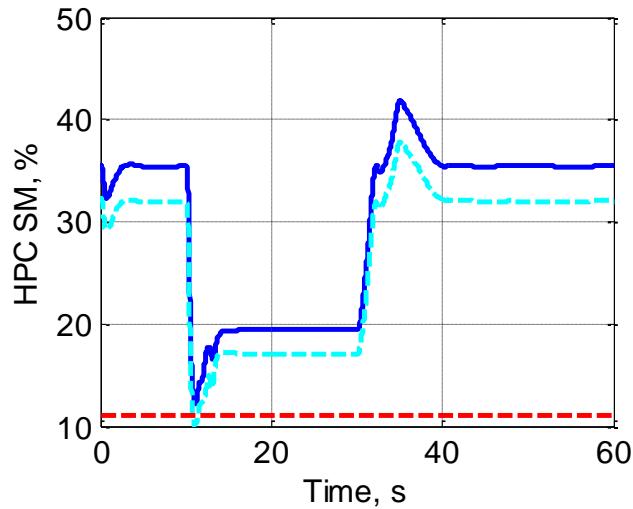
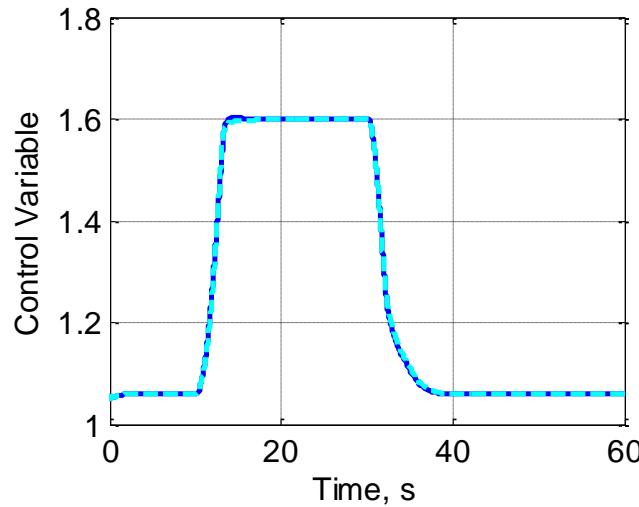
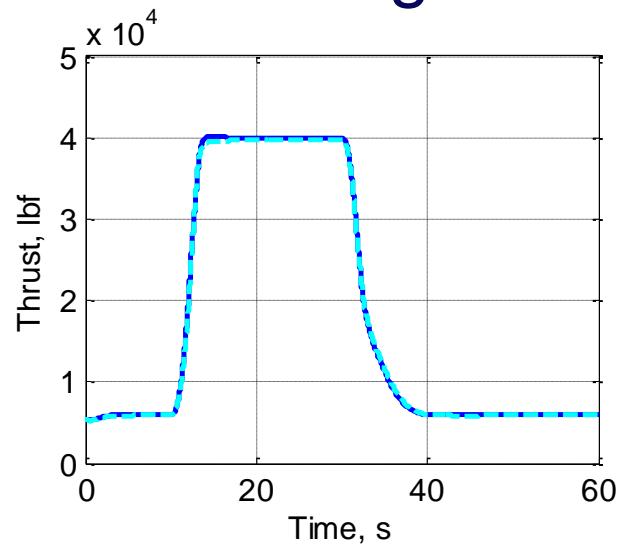


- Idle (14% of max thrust) to Take-off thrust profile to test the TTECTrA controller
- Compare the thrust response to the Federal Aviation Administrations (FAA) Federal Aviation Regulation (FAR) Part 33, Section 33.73(b)

Burst and Chop Thrust Profile



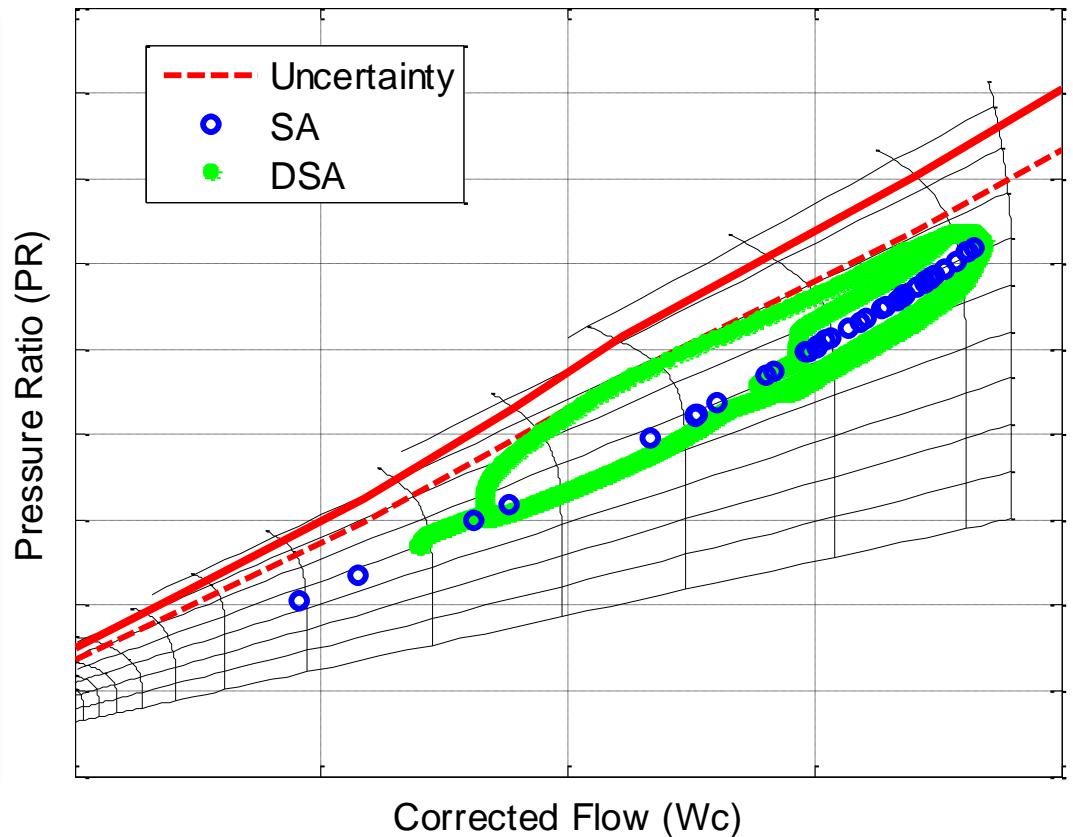
Engine Deterioration



The Benefit of TTECTrA

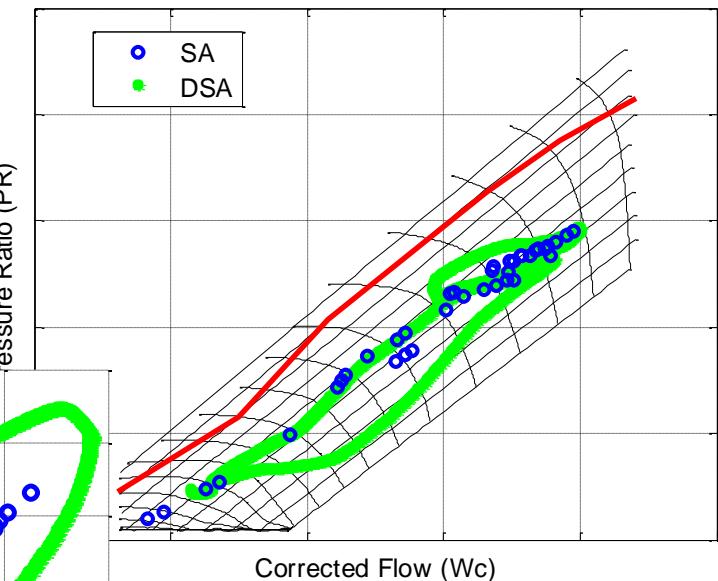
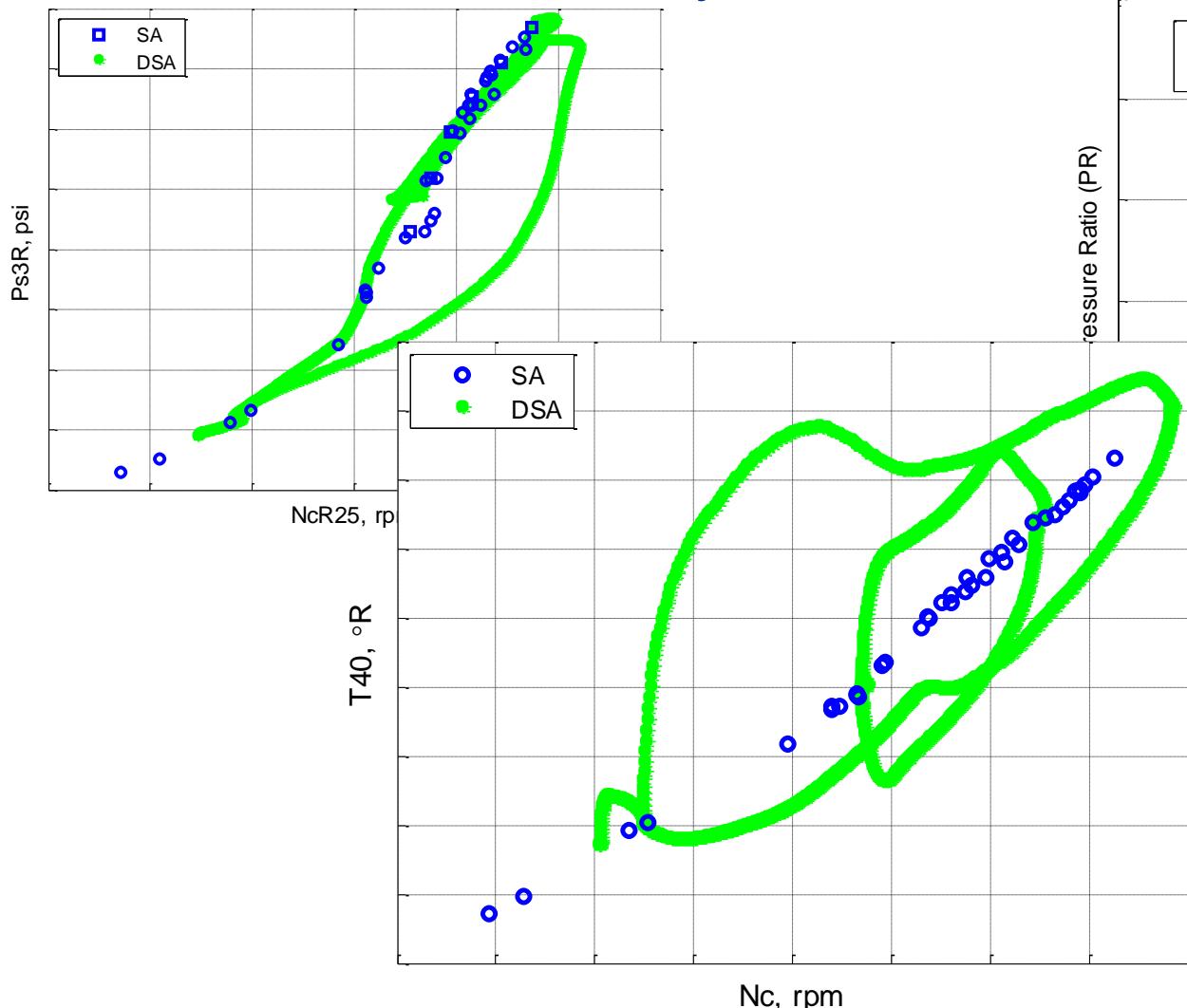
Do we have enough margin? Too much margin?

Stack	%
Uncertainty	11
Reynolds Number	2
Distortion	4
Tip Clearances	1.5
Deterioration	1.5
Random	2
Transient Allowance	12
Total	23



The Benefit of TTECTrA

- Combustor Stability



- Low Pressure Compressor
- Turbine life



Future Work

- NPSS Model in Simulink
 - Georgia Institute of Technology
- Integrate TTECTrA with the NPSS Simulink model
 - NASA/RHC
- Integrate TTECTrA/NPSS Simulink with a larger systems analysis optimization algorithm
 - NASA/RHC and NASA/RTM



Conclusion

- Dynamic systems analysis:
 - Enables engine transient performance to be accounted for in the optimization of the engine design and early in the preliminary design of turbine engines.
 - Allows trading of overly conservative surge margin for better performance through system redesign (or opline).
- Developed the Tool for Turbine Engine Closed-loop Transient Analysis (TTECTrA)
 - Capable of automatically designing a controller at a single flight condition.
 - Easily integrates with users engine model in MATLAB/Simulink environment.
 - Open source



Thank you
Questions?